RESPONSE TO UINTA BASIN COMPOSITION STUDY REVIEW

Utah Division of Air Quality

Introduction

The Uinta Basin Composition Study (UBCS) final report was released on March 31, 2020. On February 5, 2021 the Utah Division of Air Quality (UDAQ) received Utah Petroleum Association's (UPA) Review. UDAQ appreciates UPA's Review (the Review) and offers a response to the Review's main points:

- sample representativeness and integrity
- characterization of the heavier portion of the liquid samples in the equation of state model
- unusual operating conditions reported
- use of an arithmetic mean instead of the more representative median to determine mass emission rates.

The UBCS included the sampling at 78 well pads, contemporaneously collected and analyzed with uniform QA/QC procedures and acceptance criteria, and performed by a single contractor. This improved upon the emission inventory currently in place for which documentation included a variety of sample dates (some as old as 2001 and some without test dates indicated), unidentified test methods, QA/QC criteria omitted, and single samples used to represent hundreds of wells. The UBCS also resulted in better characterization of oil and gas emission stream speciation profiles used to update the triennial oil and gas emissions inventory used in on-going photochemical modeling exercises. The speciation of those emissions and the variability in reactivity rates in forming ozone are critical for improving performance of photochemical ozone modeling.

The waxy crude produced and stored in heated tanks introduced learning opportunities in the collection and analyses of pressurized liquid hydrocarbon samples and, with extensive consultation with ProMax, considerations that can be used in modeling the process emissions using equation of state/process simulation modeling (EOS/PSM). UDAQ did reexamine the EOS/PSM regarding the modeling of C10+ and agrees with UPA's recommendation in the characterization of the heavier portion of the liquid samples.

The Review states that abnormally high separator pressures "are unusual and unlikely as this would result in a host of operational problems from gas carryover including high tank pressures that would breach thief hatch seals or activate pressure relief valves." In this response, UDAQ provides a comparison of operating parameters observed in the UBCS with data submitted by operators as a part of the pre-planning of the UBCS, Tribal Minor Source Registrations, permit applications and emission inventory submittals. The UBCS parameters fall within the range of these other data sources; therefore, the available data indicates these separator pressures are not unusual or unlikely. In addition, from studies and inspection observations in the Uinta Basin, tank emissions are observed venting to atmosphere through thief hatches and pressure relief valves at about 30%-50% of production sites.

The Review questions the use of an arithmetic mean instead of the more representative median to determine mass emission rates. For emissions inventory applications, UDAQ is interested in estimating total emissions for the Basin over a year. A mean proportionally represents all available data, whereas the median would represent more typical operation. The mean is most appropriate for inventory application goals because regulators seek an emission factor that allows for basin-wide emissions estimation. The use of emission factors is helpful in making emission estimates for area-wide inventories; however, UDAQ acknowledges that site-specific information is highly preferred for permitting and establishing regulatory controls.

UPA's Review also concluded that UBCS results should not be used for any policy or regulatory purpose without further review and reconsideration. The primary purpose of the UCBS was to improve the accuracy of the emission inventory and upcoming photochemical modeling. Any future rulemaking or regulatory actions will be proposed through stakeholder involvement and the public comment process. The UBCS also was intended to support the permit application process. The UBCS findings can assist in evaluating permit applications that rely on EOS/PSM models and to ascertain the appropriateness and quality of the pressurized liquid samples. The UBCS will also allow operators who do not want to gather site-specific information to create their own site-specific tank emission estimates, rather, they could utilize the average oil tank and condensate tank emission factors found in the UBCS.

UDAQ appreciates UPA's offer of their expertise and operational knowledge to partner with UDAQ moving forward. This will prove useful as UDAQ works on the development of tank emission estimating guidance.

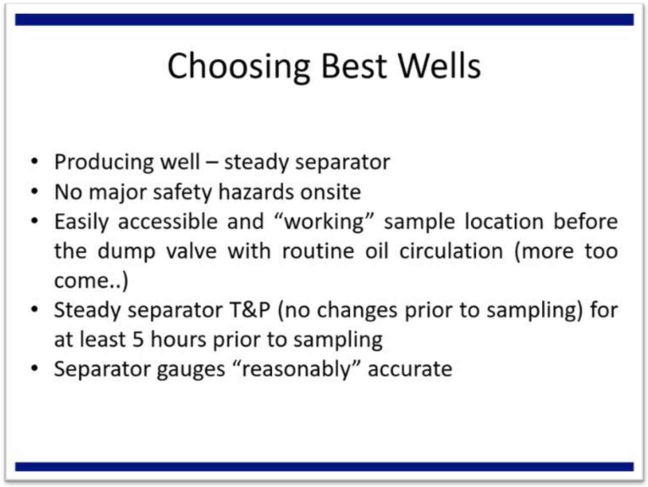
Sampling

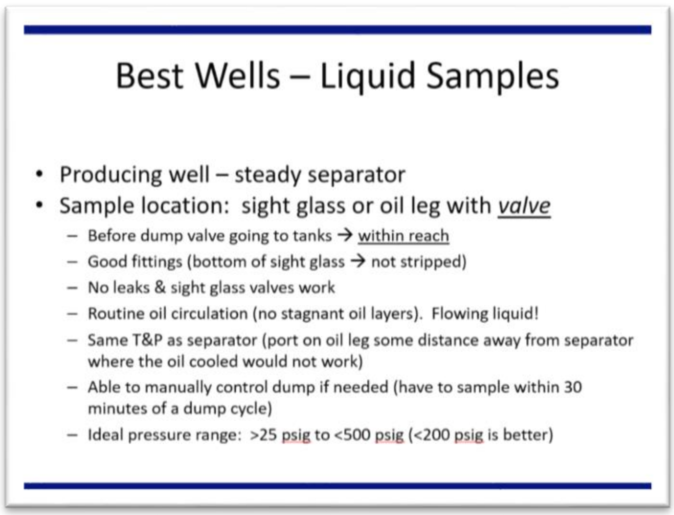
Sample Representativeness

Every effort was made to obtain a large, representative sample distribution for the UBCS. UDAQ sampled as many wells as possible at the time, given the number of Uinta Basin operators willing to participate in the study, and the amount of funding available for the project. Operators who did participate in the study were given the opportunity to help the primary investigators (PI's) select sites most appropriate for sampling. PI's generated a list of sites for each operator that reported production from representative geological formations in the Basin (data were sourced from the Utah Division of Oil, Gas, and Mining (UDOGM)). Operators selected a subset of sites from that list which would meet the pre-sampling protocol (see next section). The PI's then narrowed the list of sites selected to meet project budget constraints for total number of samples and inclusion of corroborating samples like stock oil API gravity and flash gas emission measurements.

Pre-Sampling Protocol

Alliance Source Testing (AST), UDAQ's contractor, and UDAQ prepared a pre-study workshop for all operators invited to participate in the UBCS on 9/13/2018. Pre-sampling protocols were included in this workshop, and the slide deck containing pre-sampling protocols were shared with operators prior to field sampling. These slides are reproduced below:





Separator Pressures

The Review raised concerns about "abnormally high and unexplained separator sample pressures." To evaluate this concern, UDAQ compared the distribution of separator pressures measured in the UBCS with calibrated probes to other available separator pressure data:

1. UDAQ Permits - Separator pressures collected from lab reports (pressurized liquids or flash gas analysis) from UDAQ permits or NOIs[1]
2. Operator Sheets - Separator pressures reported by operators in spreadsheets to the PIs prior to well selection and participation in the UBCS
3. Tribal Minor Source Registration (TMSR) - Separator pressures reported by operators in EPA's TMSR program.
4. UBCS – Separator pressures measured with calibrated probes in the field at the time of sample collection.
5. UBEI2017 - Separator pressures reported by operators to the 2017 Uinta Basin oil and gas emissions inventory

[1] DAQ permits were manually scanned for flash gas laboratory reports in late 2017.

Box and whisker plots below show the separator pressure and temperature ranges from these data sources. The mean of each distribution is shown by a red point, and the median is a black line. Markers on the box and whisker plots show the data values which compose the distribution. The Review claims that separator pressures recorded in the UBCS are "unusually high," but the figures below show that the recorded pressures are within ranges reported by operators to other regulatory data sources.

Separator Pressure, psig (Oil wells only)

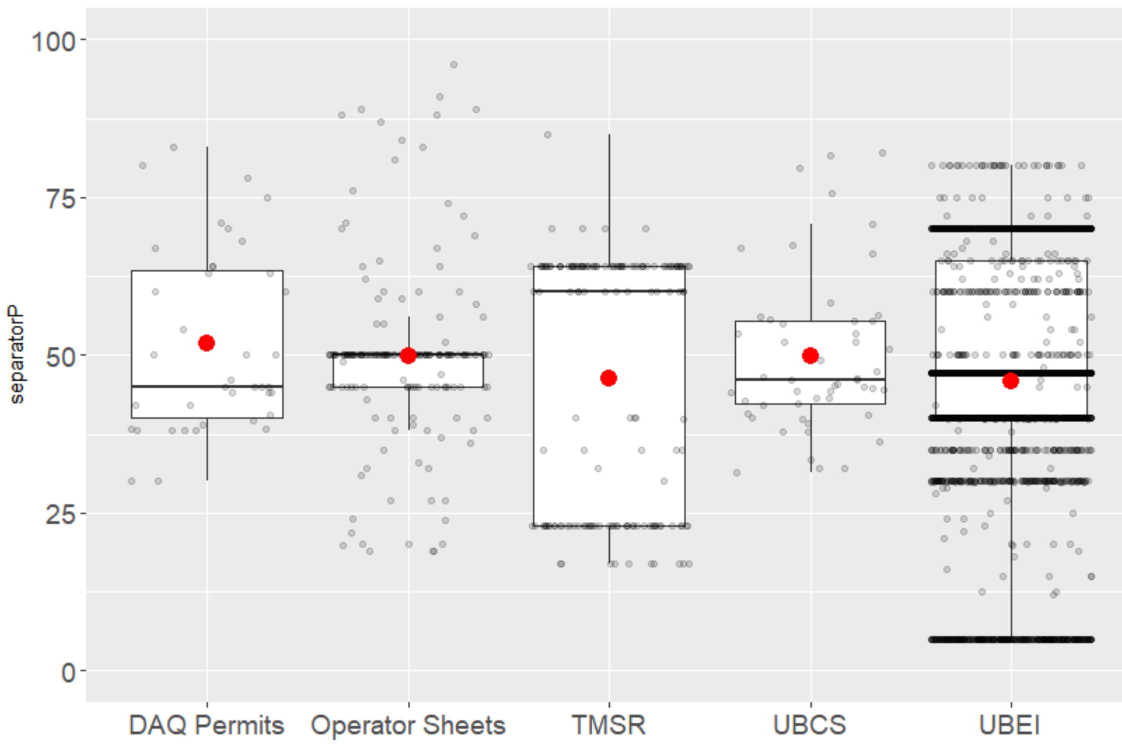


Figure 1: Separator pressure distributions for oil wells. Two outliers were removed from the UBEI dataset (150 and 450 psig) so that the other distributions could be easily visualized in this figure (zoomed). The mean of each distribution is shown by a red point, and the median is a black line.

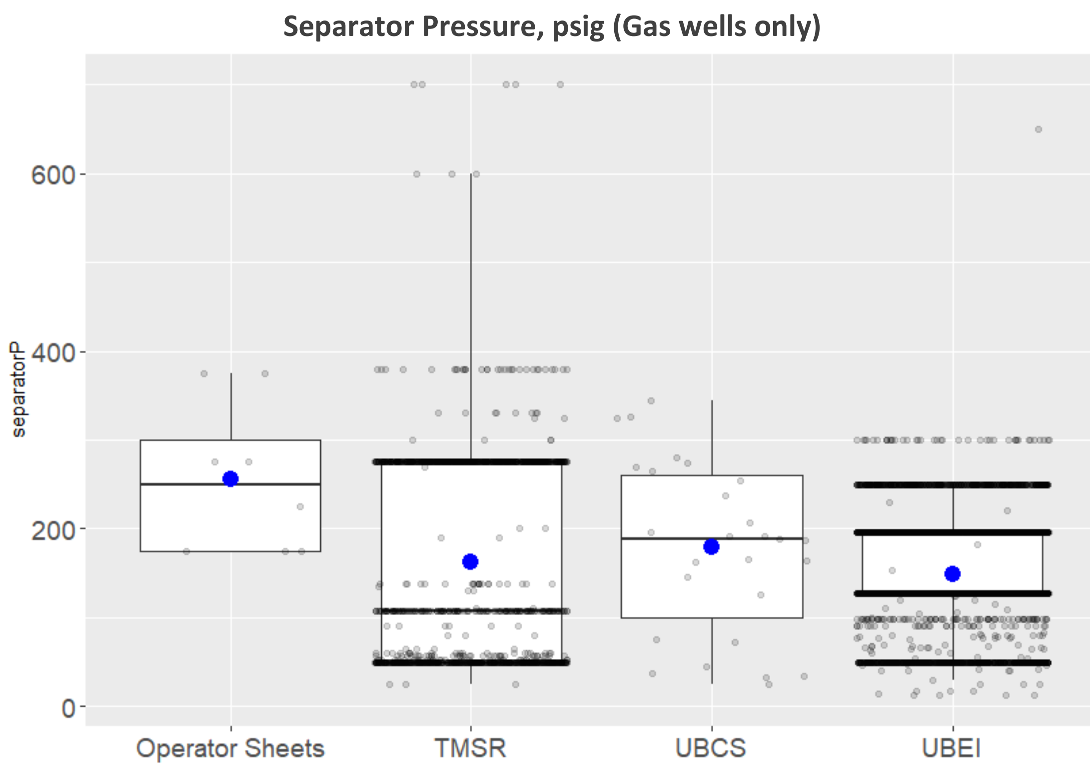


Figure 2: Separator pressure for gas wells. The mean of each distribution is shown by a blue point, and the median is a black line.

The Review goes on to state that abnormally high separator pressures "are unusual and unlikely as this would result in a host of operational problems from gas carryover including high tank pressures that would breach thief hatch seals or activate pressure relief valves." From studies and inspection observations in the Uinta Basin, tank emissions are observed venting to atmosphere through thief hatches and pressure relief valves at about 30%-50% of well sites[2].

Ambient Tank Temperatures

The Review is concerned that ambient tank temperatures reported in the UBCS are "unusually low, often below freezing." The Tank Temperature variable in the study was populated with the tank temperature read from the operator's gauge on heated tanks, most often associated with oil-producing wells. For gas-producing wells without heated tanks, the ambient temperature at the well pad was recorded as the Tank Temperature.

In ProMax simulations completed for the 5 verification wells in Report G of the UBCS, the low tank temperature for gas wells is irrelevant because all 5 verification wells were oil wells. Oil wells were intentionally exclusively selected to verify repeatability of the EOS/PSM performance for heavy, waxy crude.

Process simulation modeling (PSM) performed for the UBCS performed slightly differently for facilities with heated tanks, in which the flashing temperature was held constant at the heated tank temperature. For facilities without heated tanks (gas wells), the flashing temperature was *not* held to the Tank Temperature variable which, in this case, would have been the below freezing ambient temperature. Flashing

[2] "Gap Fill Tank Emissions Not Making to Combustor" https://documents.deq.utah.gov/air-quality/inventory/DAQ-2021-002370.pdf

temperatures were estimated according to the PSM's equation of state (EOS). UDAQ acknowledges that this was not made clear in the UBCS final report. UDAQ disagrees that low ambient temperatures "call into question the integrity of the Study data used for modeling," as stated in the Report.

Post-Study Protocol

After sampling and analysis were completed by AST, all raw lab reports and a summary spreadsheet were shared with operators involved in the UBCS. These data were shared in March 2019. Operators had the opportunity to share concerns about operating conditions or other data anomalies, but no comments were received.

Sample Acceptance Criteria

Acceptance criteria for samples collected and analyzed in the UBCS were based on findings from the Noble Energy Pressurized Hydrocarbon Liquids Sampling and Analysis Study[3].

Operational performance checks (OPCs) are designed to evaluate whether the composition of a pressurized liquid sample is a reasonable representation of the process stream composition at gas/liquid equilibrium. The Noble Energy Study recommends several operational performance checks that could help determine whether a sample is acceptable or is somehow flawed. AST subcontracted with Innovative Environmental Solutions (IES) to determine appropriate OPCs for the UBCS dataset because IES led efforts to define "Operational Performance Checks for Pressurized Hydrocarbon Liquids Sample Collection and Analysis" for the Noble Energy Study. This work represented the most detailed, deliberate, and thorough investigation of pressurized liquids sample quality at the time the UBCS was scoped

OPCs for UBCS

Additional background regarding the sample acceptance criteria may be helpful, so we provide more description below.

The ratio of bubble point pressure to sample collection pressure (P_{BP}/P_{SC}) is a useful metric to determine if the sample was collected at gas/liquid equilibrium where the ratio is close to 1.0. Samples in gas/liquid equilibrium yield accurate analytical results.

"PSM/EOS calculated P_{BP}/P_{SC} could be used as a conservative OPC for samples collected to estimate Flash Gas-Oil Ratio (FGOR) and flash gas composition. …For this study, P_{BP}/P_{SC} ranged from about 0.73 to 1.16, and this range could be a minimum for OPC acceptance criteria" (Noble Energy Study, 2018).

IES (Tom McGrath) provided clarification to UDAQ on the UBCS acceptance criteria he developed:

> The following approach was used to evaluate the reliability of the Utah LHC [liquid hydrocarbon] samples. The P_{BP}/P_{SC} ratios for the population of the waxy crude samples had a normal probability distribution and common statistical tools were used to identify potential outlier samples based on the P_{BP}/P_{SC} ratio (i.e., identify samples that were not representative of the population of samples). The properties of these potential outlier samples (e.g., FGOR and ethane and propane content) were

[3] https://noblecolorado.com/wp-content/uploads/2018/12/SPL_PHLSA-Study_Final-Report_020718.pdf Noble Energy Study (2018) – see Section E.3.2, Section 4.6 and Appendix VI of the "Pressurized Hydrocarbon Liquids Sampling and Analysis Study Data Assessment and Analysis Report", Southern Petroleum Laboratories, Inc., February 7, 2018

further analyzed and one sample was estimated to be non-representative. A secondary check was to determine if the P_{BP}/P_{SC} ratios were in the range of 0.70 to 1.3. This P_{BP}/P_{SC} range sample acceptance criteria was provided by EPA's technical consultant to the SPL study, and was based on an analysis of liquid HC samples collected from over 100 different production sites with separator pressures ranging from about 3 to 300 psig. This P_{BP}/P_{SC} range (0.70 to 1.3) is similar to the range identified by the SPL study as a potential minimum for the OPC acceptance criteria (i.e. 0.73 to 1.16), providing confidence in these ranges. The SPL study samples were collected from a single production site (over a range of separator pressures and temperatures) whereas the EPA's technical consultant samples and the Utah study samples were both collected from a large number of production sites; therefore, EPA's technical consultant P_{BP}/P_{SC} range (0.70 to 1.3) was considered more applicable to the Utah study samples.

Acceptable P_{BP}/P_{SC} ratios ranging from 0.7 to 1.3 is the same as a +/- 30% difference between the bubble point pressure and the sample collection pressure. EPA's technical consultant, with extensive domestic and international upstream oil and gas experience, elucidated that the +/- 30% difference range is an engineering estimation based on the following sources of uncertainty in sampling:

- Inaccurate gas chromatograph component analysis, +/-5% or more, especially at low separator pressures
- Inaccuracy and/or errors in sample handling and preparation at the receiving laboratory
- Inaccuracy in recorded process temperature and pressure values at the sample point
- Inaccuracy in equation of state predictions, +/-6% or more, especially for high density fluids like waxy crude

The +/-30% value is believed to be conservative with respect to the maximum expected difference between predicted and reported separator operating pressures determined for pressurized liquid samples, allowing room for the challenges of working with the Uinta Basin's waxy crude.

Alternative Acceptance Criteria

The Review recommends that UDAQ leverage OPC ranges such as those used by CDPHE. This table was developed by FESCO, AST, and Zedi according to their experience and professional insight to acceptable sample quality at various pressure ranges. EPA followed up with CDPHE and CARB to understand the origins of the step-function of P_{BP}/P_{SC} to separator pressure. Both agencies identified FESCO as the source of this acceptance criteria. EPA spoke with David Dannhaus of FESCO to learn more about the development of their table. FESCO reiterated that the table was not based on nor necessarily prepared for heavy waxy crude samples. Given the low pressure, high paraffin and heavy hydrocarbon samples found in Utah, UDAQ contends that a +/-30% acceptable percent difference range as an OPC is appropriate for the stated objectives of the UBCS.

The Noble Energy study advises that "acceptance of pressurized HC liquids composition results should depend on the ultimate data use and engineering judgment." The objectives of the UBCS were to understand the unique composition of Uinta Basin oil and gas products. Broadly applying acceptance criteria from other oil and gas basins based on lighter crude *does not* align with the goals of the study. Engineering judgement by experts in the field determined the acceptance criteria leveraged in the UBCS. While these acceptance criteria will be upheld for the UBCS, UDAQ and EPA are open to discussion with UPA on sample acceptance criteria for regulatory applications in the future.

Process Simulation Modeling

Process Simulation Modeling (PSM) for the hydrocarbon sampling dataset was performed by AST using VMGSim. Using ProMax, UDAQ endeavored to learn more about PSM performance specifically for Uinta Basin waxy crude. This model validation was attempted on a subset of 5 pressurized liquid samples. The goal of this validation exercise described in the UBCS final report was intended to explore model sensitivity to the uniquely waxy crude extracted from the Uinta Basin. The results from the 5 resampled wells compared well with the original results, and VMGSim and ProMax were comparable.

Decanes Plus Consideration

The Review claims that UDAQ failed to leverage ProMax's ability to exactly model decanes plus (C10+) instead of modelling C10+ as C10. UDAQ consulted with ProMax to understand this claim and reran ProMax to utilize the model's more refined C10+. The figures below show UDAQ's previous ProMax simulated tank emission factors (lb/bbl) including flash and AP-42 working and breathing emissions compared to updated ProMax simulations including the C10+ consideration. Note that, in addition to the C10+ adjustment, UDAQ also updated the ProMax simulation to emulate AST's process simulation modeling and Ramboll's recommendation for ambient tanks by *not* forcing the flashing temperature to ambient temperatures and allowing the EOS to calculate the flash temperature at gas well sites. This can be observed in the significant increase in emission rates from gas wells associated with company III.

A slight increase in emission factors is observed for most oil wells using the correct C10+ characterization. A decrease is observed in the average emission factor for gas wells. The UBEI2017-Update white paper shows an increase (from UBEI2017) in VOCs from condensate tanks of +3658 TPY VOCs. With adjustments to the flashing temperature *and* C10+ characterization, total additional VOCs from condensate tanks is +2188 TPY VOCs. For oil wells, the C10+ adjustment result in an increase of +1701 TPY VOCs (compared to +1411 TPY in the white paper.) These adjustments to VOC totals from tanks will be reflected in UBEI2017-Update in an upcoming revised white paper version.

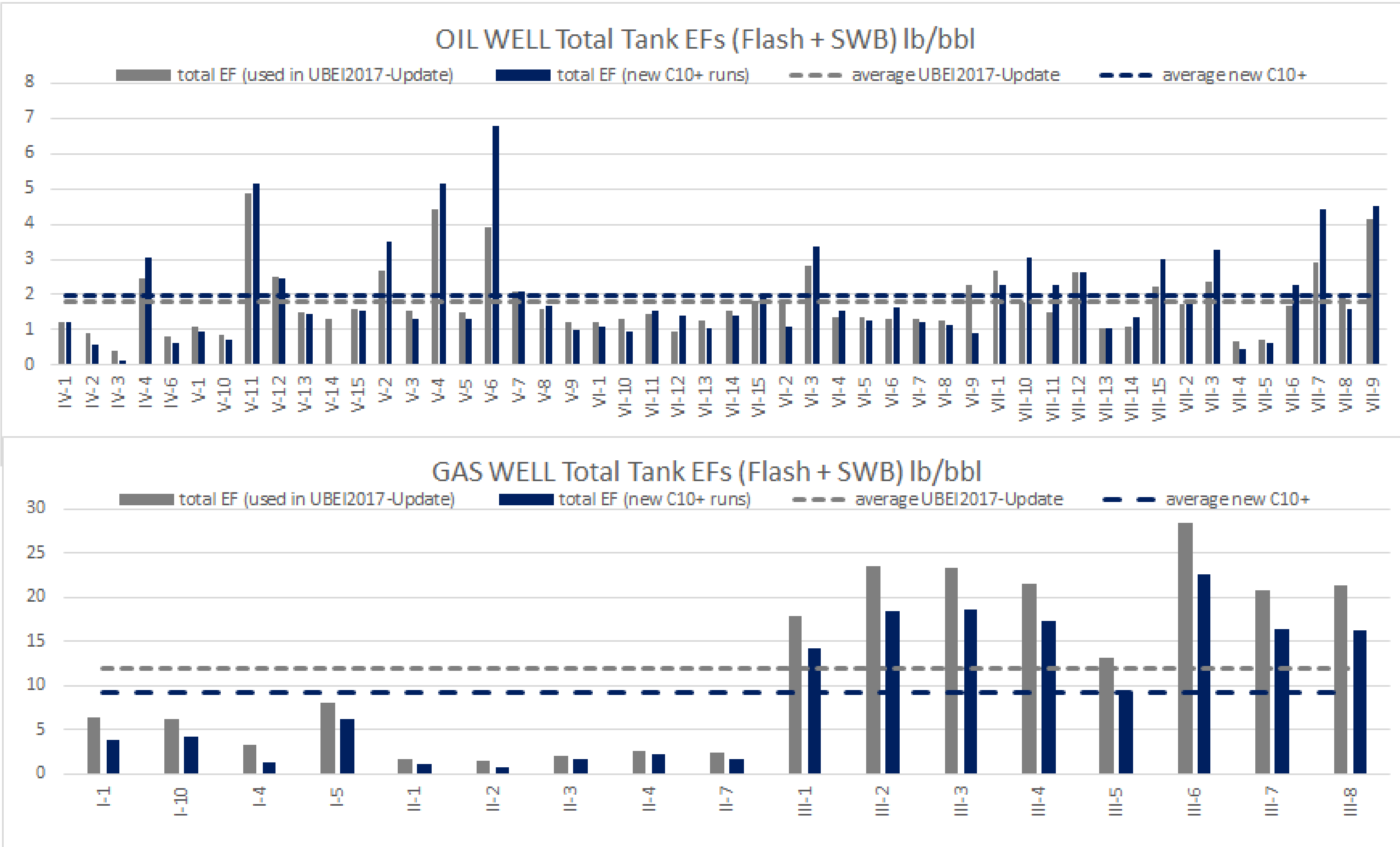


Figure 3 (TOP) Tank emission factors (EFs) in lb/bbl (shown on Y-axis) for all UBCS oil wells, and (BOTTOM) Tank emission factors (EFs) in lb/bbl for all UBCS gas wells. Gray bars show ProMax runs without C10+ characterization and forcing flashing T to be ambient T (for gas wells only). Navy bars reflect the C10+ consideration and an adjustment to allow EOS estimation of flashing T for unheated tanks (gas wells).

Tank Emission Factors & FGOR

Tank emission factors in Report G of the UBCS were never intended to serve as a generalized emission factor. The demonstration in Report G is an investigation into EOS/PSM behavior for heavy crude sent to heated storage tanks. Figure 4 (above) shows emission factors calculated for all wells in the UBCS. It is noted that the 5 verification wells represent higher emission factors than the more frequent factors in the 1-2 lb/bbl range; the wells with higher FGORs were selected for the verification effort to confirm the repeatability of findings.

The Review claims that "skewed data sets such as these are better represented by a median, whereas in this case, the mean of a left-skewed data set overestimates the central tendency."

For emissions inventory applications, regulators are interested in estimating total emissions for the Basin. A mean proportionally represents all available data, whereas the median would represent more typical operation. The mean is most appropriate for inventory application goals because regulators seek an emission factor that allows for basin-wide emissions estimation.

Operator tank emission factors in the UBEI2017 were not overwritten by updated tank emission factors from the UBCS. Instead, operator emission factors were leveraged to make an adjustment to total tank VOC emissions based on findings in the UBCS.[4]

Model Validation

Stock Tank Oil API Gravity Measurement

UDAQ agrees that physical measurement of the stock tank oil API gravity would have assisted in model validation. This was explicitly acknowledged on page 137 of the Uinta Basin Composition Study Final Report: "A sample from the storage tank to derive the Sales Oil API gravity and RVP should be done contemporaneously with pressurized liquid samples from the separator." The Air Agencies welcome input from UPA on appropriate methods and protocols for ascertaining API gravity of stock oil for this waxy crude stored in heated tanks.

Physical Flash Gas Measurements

When scoping the UBCS, PI's were told by most laboratories contacted for quotes that physical flash gas measurement of Uinta Basin waxy crude would "gunk up" the flash gas measurement instrumentation. As a replication of flash that may occur in the field, most laboratory environments were not equipped to insulate the heated crude and flash into a simulated heated tank environment. While the PI's of the UBCS agree that additional flash gas measurements would help further understand the variability in PSM EOS outputs, limitations in funding prevented an expanded addendum to the UBCS. Regulatory Applications

Results from the UBCS have been used to update the 2017 Uinta Basin oil and gas emissions inventory (UBEI2017-Update)[5]. Although emission factors make sense when used for emission inventories covering thousands of facilities, we agree that site-specific emission estimates reflecting the operational pressures, hydrocarbon compositions and facility configuration are better and are recommended for use in permitting or regulatory determination. Some concerns raised by UPA in the Review are specific to correct modeling or measurement of emissions from storage tanks. Regulators note that EPA has not released any guidance or

[4] Uintah Basin VOC Composition Study Impacts on the 2017 Oil and Gas Emissions Inventory https://documents.deq.utah.gov/air-quality/planning/technical-analysis/DAQ-2020-016024.pdf

[5] UINTA BASIN VOC COMPOSITION STUDY IMPACTS ON THE 2017 OIL AND GAS EMISSIONS INVENTORY, November 2020 https://documents.deq.utah.gov/air-quality/planning/technical-analysis/DAQ-2020-016024.pdf

reference method to estimate tank emissions, and the UBCS represented a first effort to learn more about emissions from heated tanks.

The Air Agencies intend to draft a Uinta Basin-specific guidance document for estimating emissions from tanks. Emissions from tanks constitute a significant proportion of overall Basin emissions; therefore, consistency in tank emissions estimations is crucial to fair and effective pollutant regulation. If additional funding becomes available for future studies, additional research and stakeholder input could inform this draft guidance. UPA's input on this would be welcome, especially on points made in the Review like:

- specifications on "proper sampling ports" operators should equip separators with to better locate the oil-water interphase in lieu of using sight glasses
- field operation checklist for data to be collected during sample collection (including UPA's recommendation to note the time elapsed after purging water from the two-phase separators to assess whether the separator was able to stabilize and re-equilibrate and documentation of operational information such as stages and phases of separation, heating conditions, and tank parameters)
- recommended field sampling and analysis protocols to ascertain the API gravity of the stock oil, especially for waxy crude stored in heated tanks
- recommended protocols for corroborating field measurement of flash gas
- acceptance criteria for pressurized hydrocarbon liquid samples relative to bubble point (pressure and temperature? Different criteria for waxy crude versus condensate? etc.)
- defining "representativeness" of pressurized liquid samples used in emission estimates for regulatory purposes
- recommended lab protocols for flash liberation of gas especially from waxy crude (e.g. use heated bath to model tank temperature? Extend analysis to C10+ or C36+? etc.)
- appropriate EOS/PSM models and how to use appropriately to model waxy crude in heated tanks
- pre-sampling protocols to ensure "normally" operating separators and how to link "normally" operating separators to "representative" operation
- creating tank emission factors correlated with the separator pressure for use in future emission inventories

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